



# **Armed Forces College of Medicine AFCM**



# **Electrical Excitability Changes in Skeletal Muscle Compared to Nerve**

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## INTENDED LEARNING OBJECTIVES (ILOs)



**By the end of this lecture the student will be able to:**

- 1- Describe with illustration the skeletal muscle electric response (**action potential**).
- 2- Describe the skeletal muscle mechanical response (**simple muscle twitch**).
- 3- Explain the **excitability changes** of the skeletal muscle during action potential.
- 4- Define **motor unite**, **motor neuron pool** and motor unite **recruitment**.
- 5- Define **all or none-law** and identify which tissues that obey

# Skeletal Muscle Electric Response = Muscle Action Potential



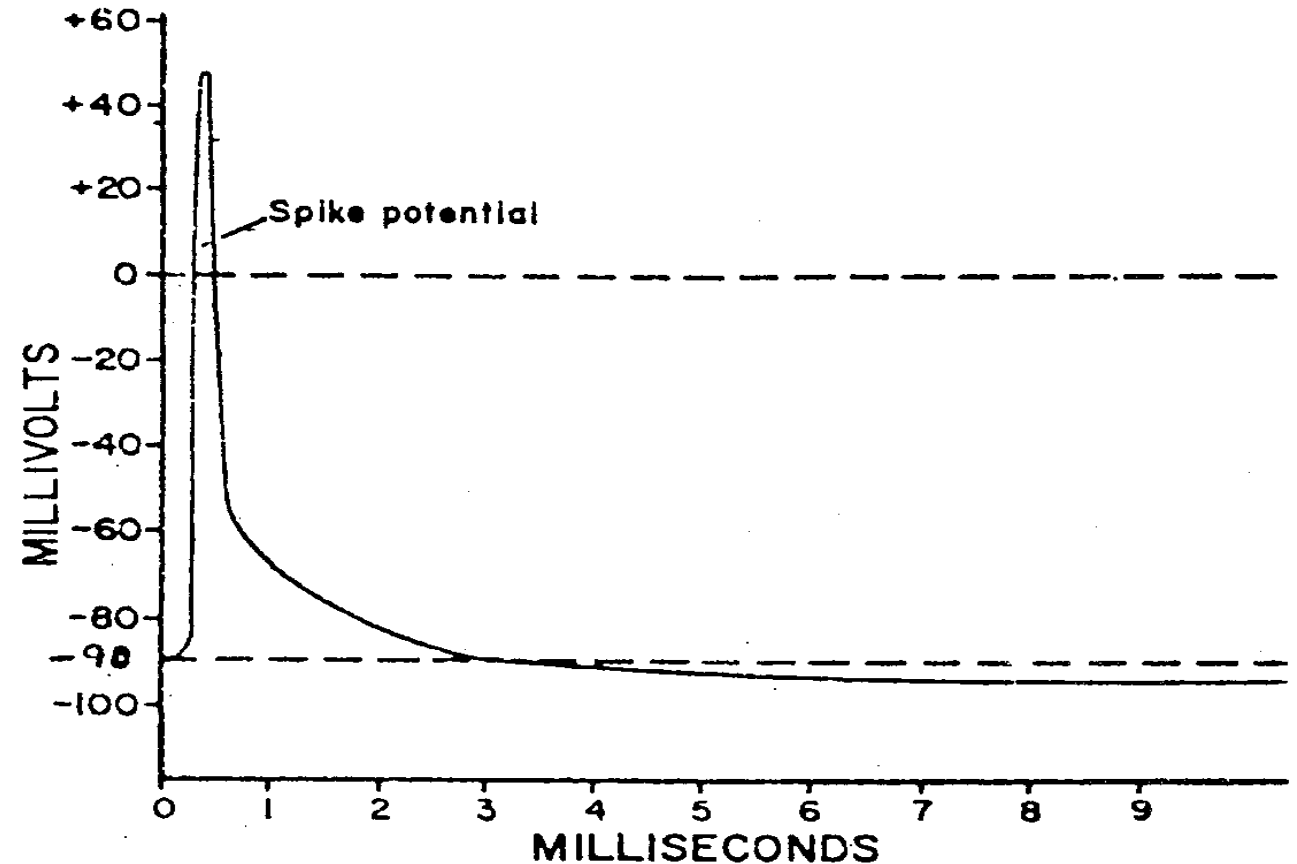
**Action potential:** Transient reversal in membrane polarity upon stimulation with an adequate stimulus.

1. **RMP:** - 90 mV.

2. **Firing level:** - 40 mV.

3. **Overshoot** up to + 40 mV.

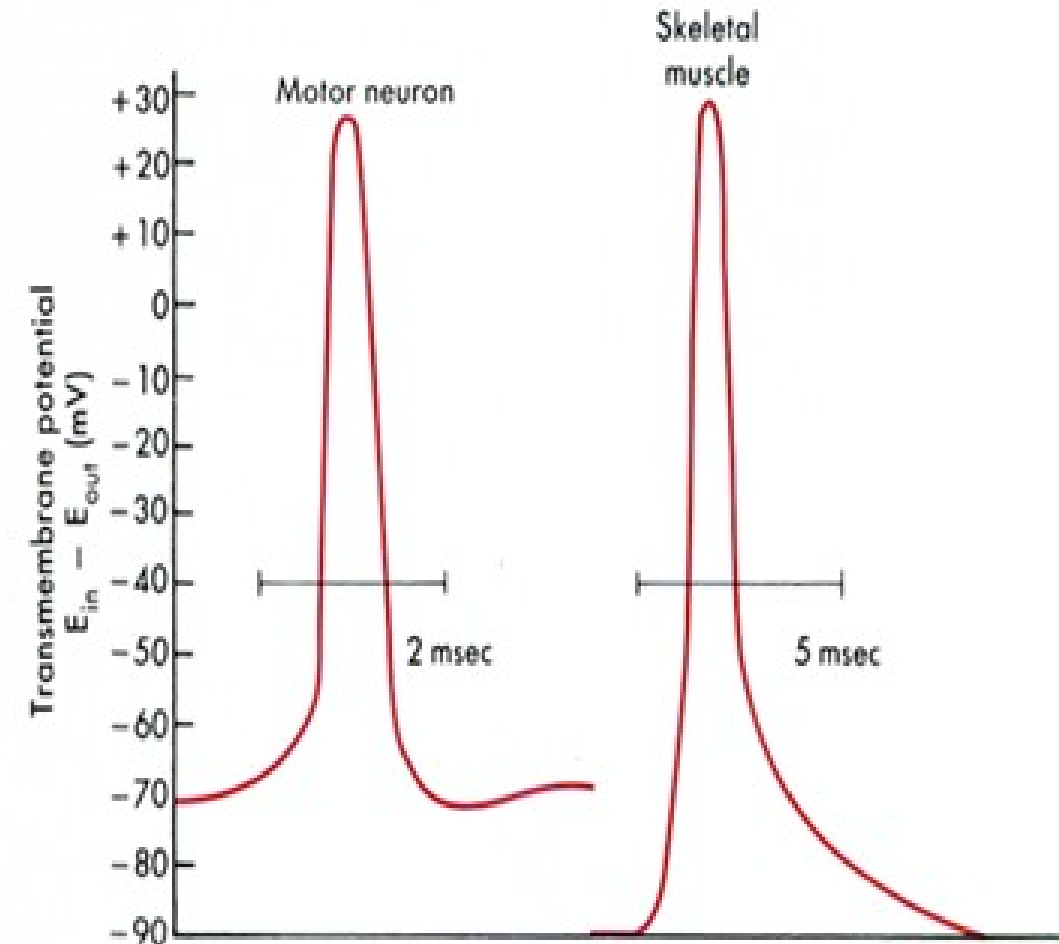
4. **Magnitude:** 130 mV (from -90 to +40 mV).



# Skeletal Muscle Electric Response compared to nerve



Nerve	Skeletal muscle	
mv 70-	mv 90-	<b>RMP</b>
mv 55-	mv 40-	<b>Firing level</b>
mv 35+	mv 40+	<b>Peak</b>
mv 105	mv 130	<b>Amplitude</b>
msec 2	msec 4	<b>Duration</b>





# **Skeletal muscle fibers differ from nerve fibers in that the former's:**

- a. Resting membrane potential is less negative.
- b. Velocity of conduction is faster than myelinated nerves.
- c. Magnitude of the spike potential is lower.
- d. Duration of action potential is longer.

# Skeletal Muscle Mechanical Response

## Simple Muscle Twitch (SMT)

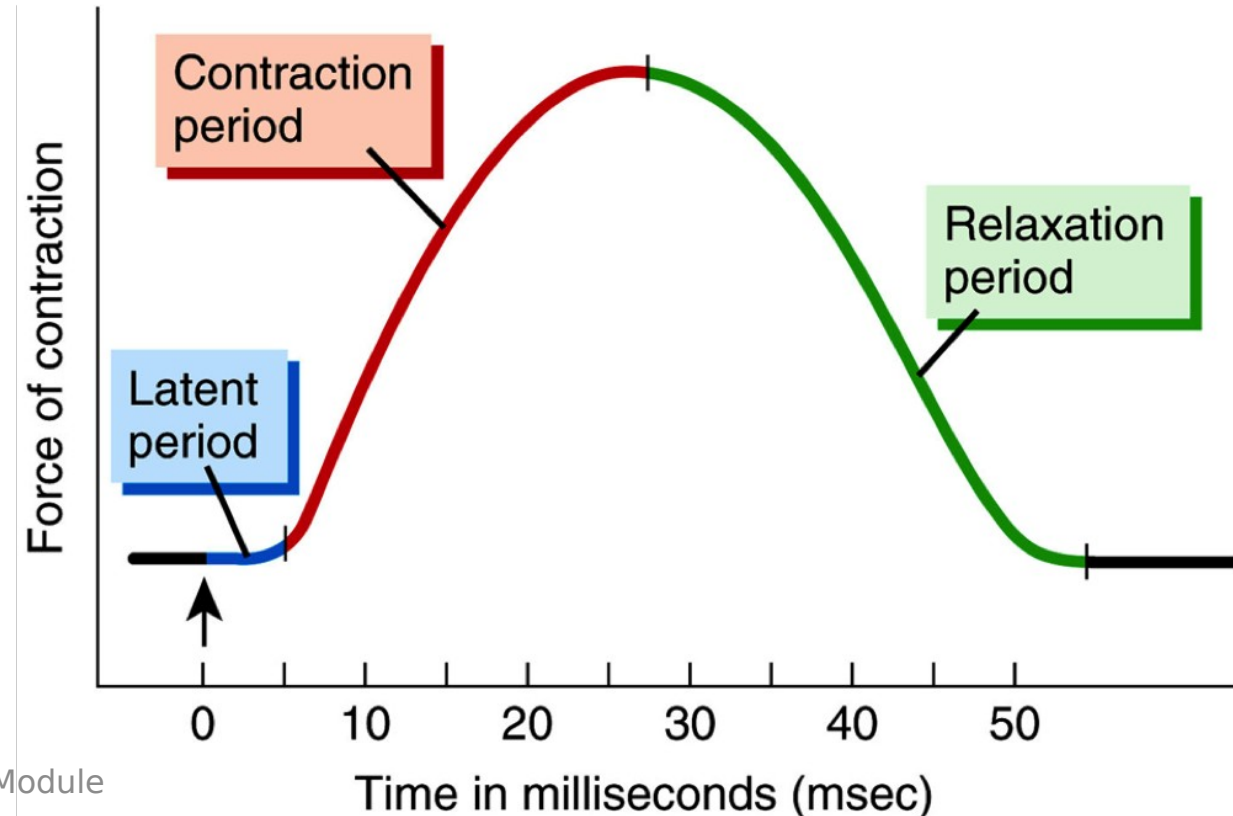


### • Definition:

It is **one contraction** followed by **one relaxation** of the muscle, produced by **single maximum stimulation**.

### • Composed of:

- (1) Latent period.
- (2) Contraction period.
- (3) Relaxation period.



# Simple Muscle Twitch (SMT)



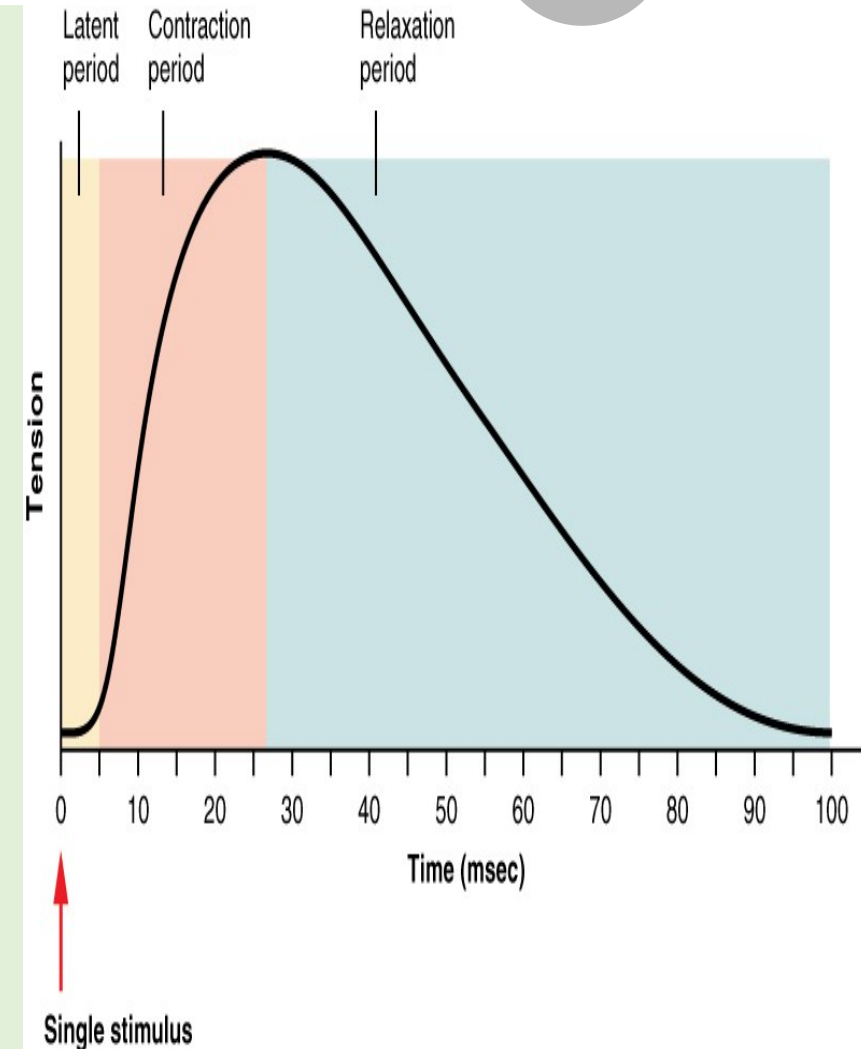
- **Latent period:** It is the time passed between the application of a stimulus till the start of muscle contraction.

## Causes:

- 1) Conduction time in its nerve supply.
- 2) Neuromuscular delay.
- 3) Conduction of action potential along the muscle membrane.
- 4) Development of the mechanical response.

- **Contraction period:** During this period, the muscle shortens, or its tension increased.

- **Relaxation period:** During this period, the muscle returns to its original length or the





# Quiz



**Complete:**

The latent period of simple muscle twitch

is.....the time passed between the application of a stimulus till the start of muscle contraction.....

.....time taken for conduction of action potential in its nerve supply,  
.....neuromuscular transmission, conduction of action potential along  
.....the muscle membrane.

**And it represents**

# **Excitability Changes of the Skeletal Muscle during its Electrical Response**



If the electrical response (action potential) and the mechanical response (SMT) are plotted simultaneously and on the same scale, it will be noticed that the mechanical response starts about 2 msec after the start of the action potential.

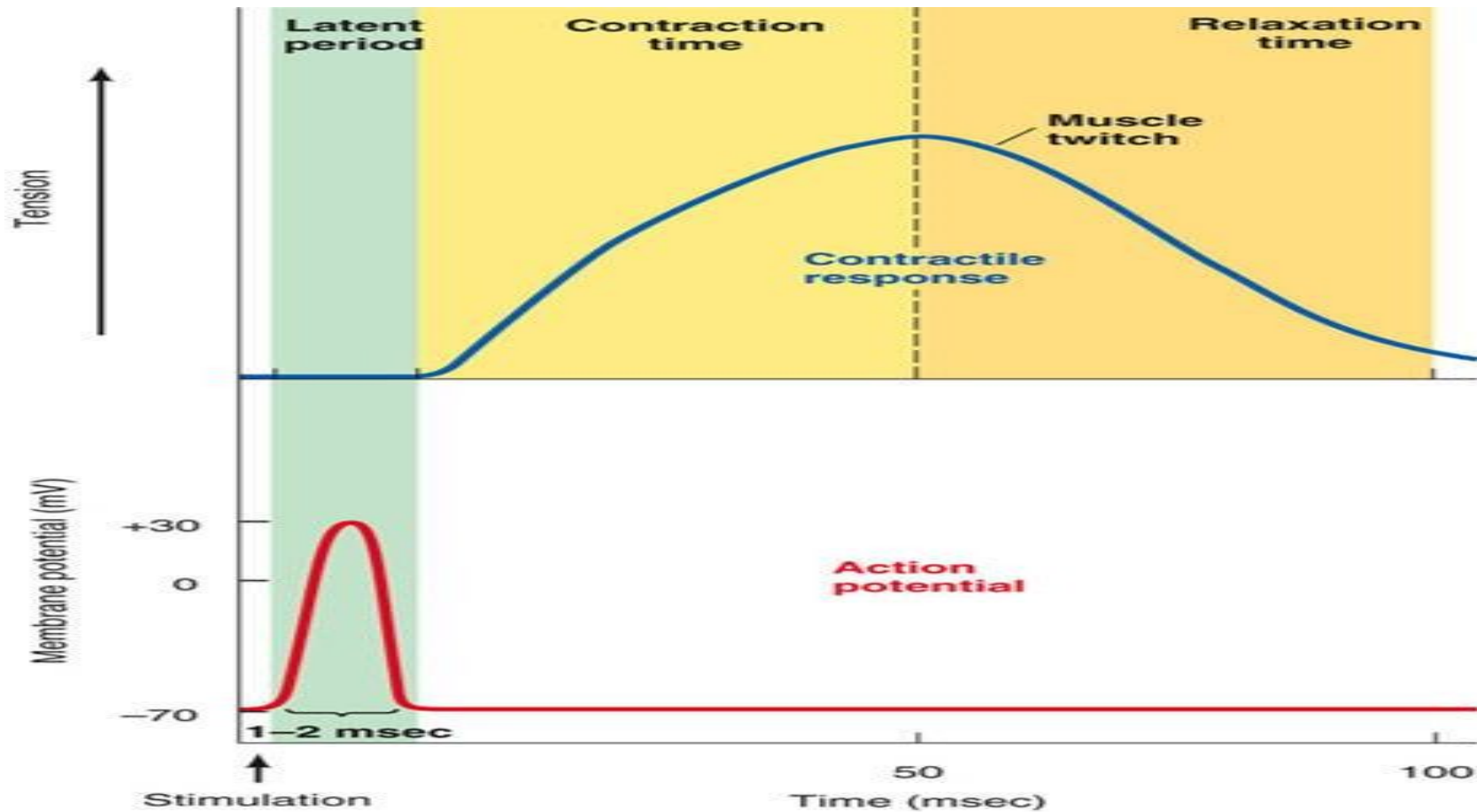
i.e.

***Electrical events precede (come before)  
mechanical events.***



# Excitability Changes of the Skeletal Muscle during its Electrical Response

***Electrical events precede (come before)***



The duration of the action potential is not drawn to scale but is exaggerated.

# Excitability Changes of the Skeletal Muscle during its Electrical Response



## **Absolute Refractory Period (ARP):**

**Electrically:** occupies the ascending limb of depolarization + upper 1/3 of repolarization.

**Mechanically:** occupies the latent period of the twitch.

## **Relative Refractory Period (RRP):**

**Electrically:** occupies lower 2/3 of repolarization.

**Mechanically:** occupies initial half of the contraction phase of the twitch.

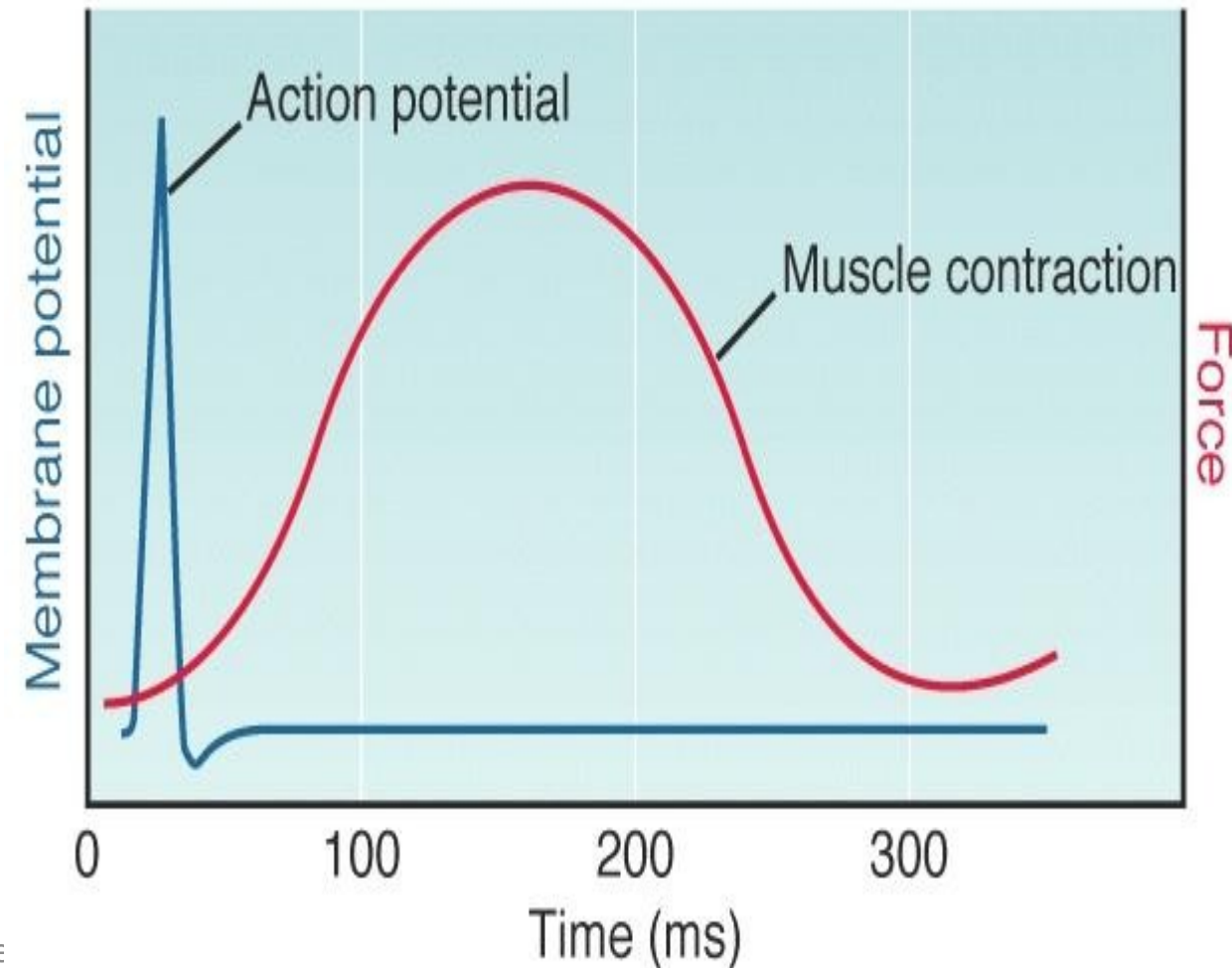
# Excitability Changes of the Skeletal Muscle during its Electrical Response



\* Therefore, during the **latent period** of the twitch, the skeletal muscle is **unexcitable** (cannot respond to another stimulation).

\* But during the **contraction period** of the twitch, the muscle can **respond to another stimulation** (i.e. **summation** of skeletal muscle contractions can occur).

(a) Skeletal muscle



## Quiz



**Complete:**

Skeletal muscle absolute refractory period

corresponds to..... of

action potential and

..... of

simple muscle twitch.

# Motor unit

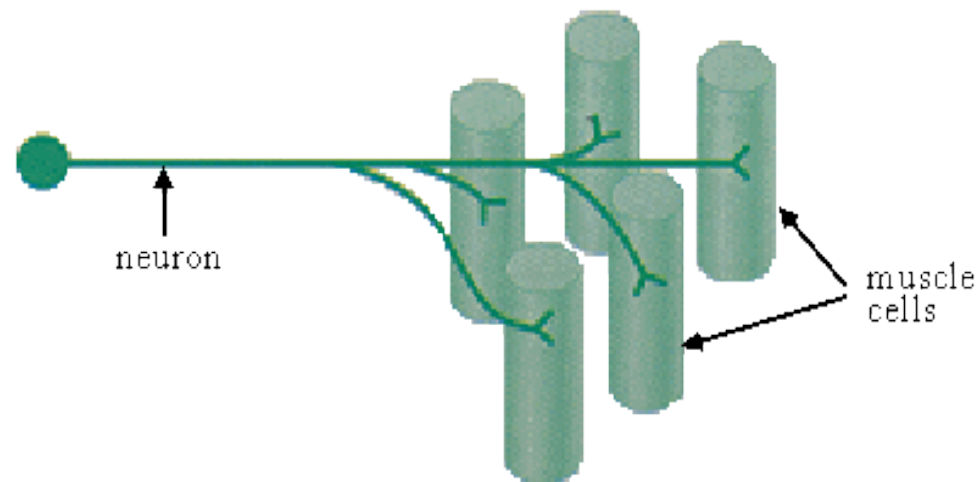


## Definition:

It is a motor neuron and all the muscle cells it stimulates.

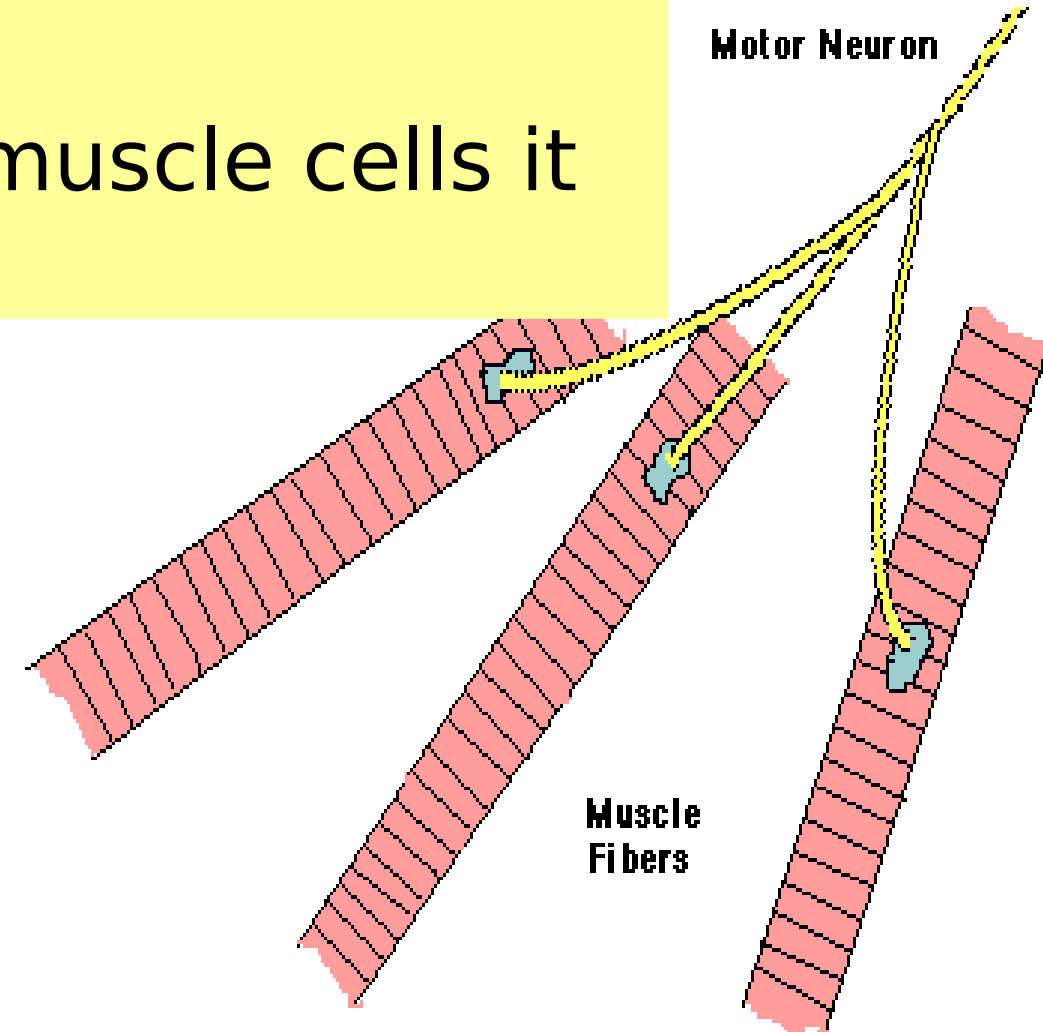
MOTOR UNITS

The combination of the motor nerve cell (neuron) and all the muscle cells it innervates is known as a motor unit

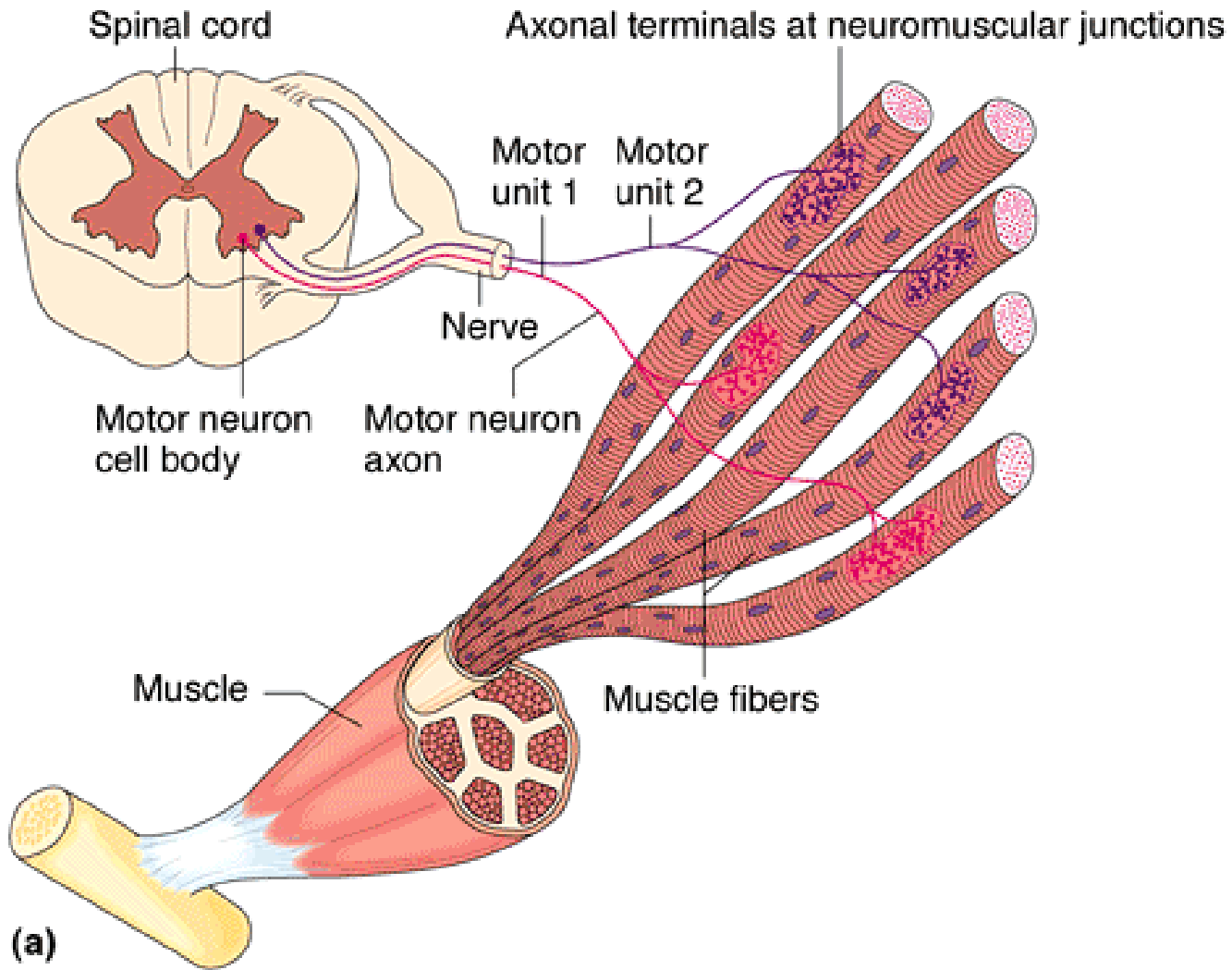


When an electrical impulse travels down the axon, all muscle cells attached to the motor unit contract simultaneously

Musculoskeletal Module

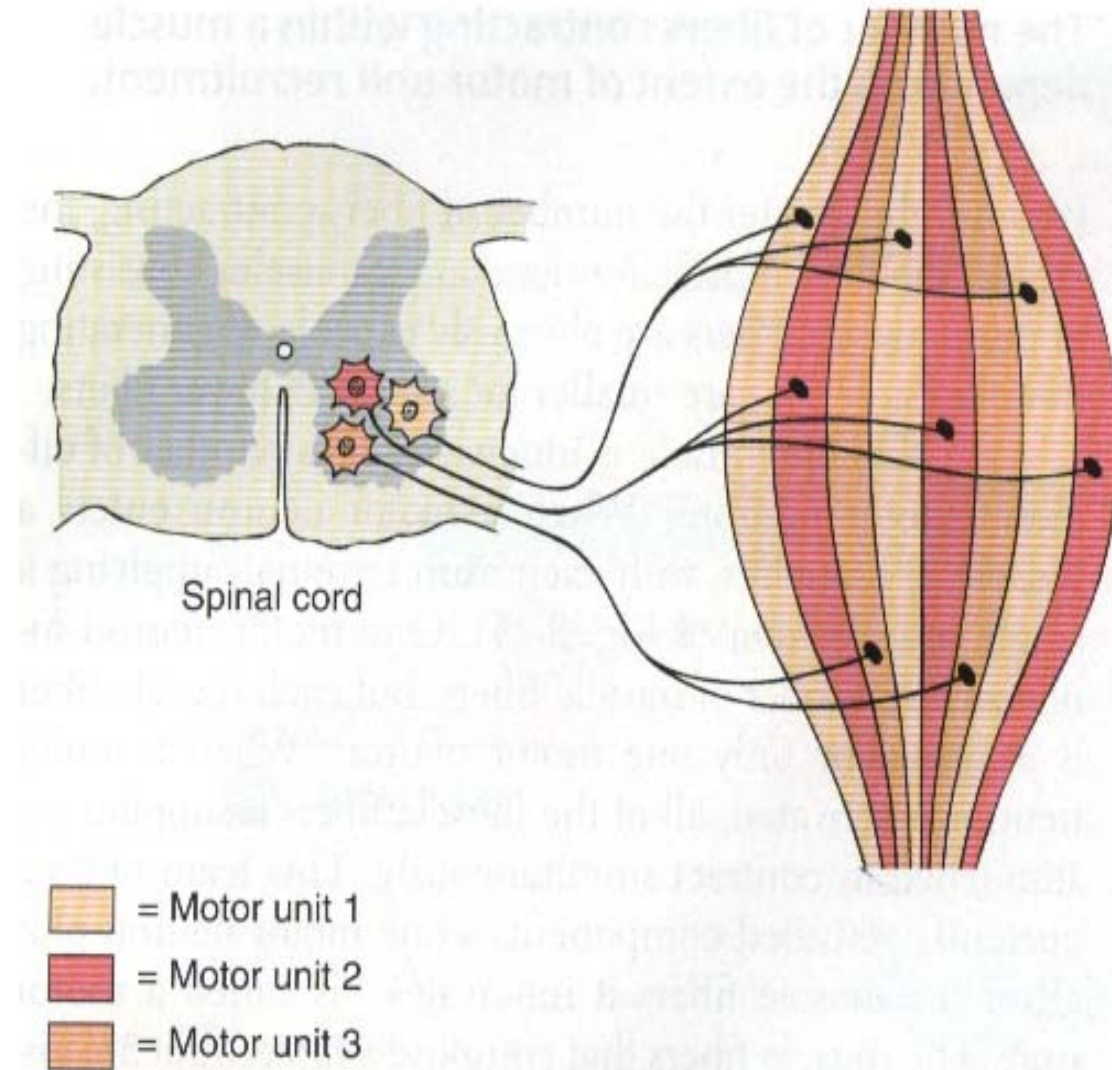


# Motor unit



(a)

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# Motor unit size



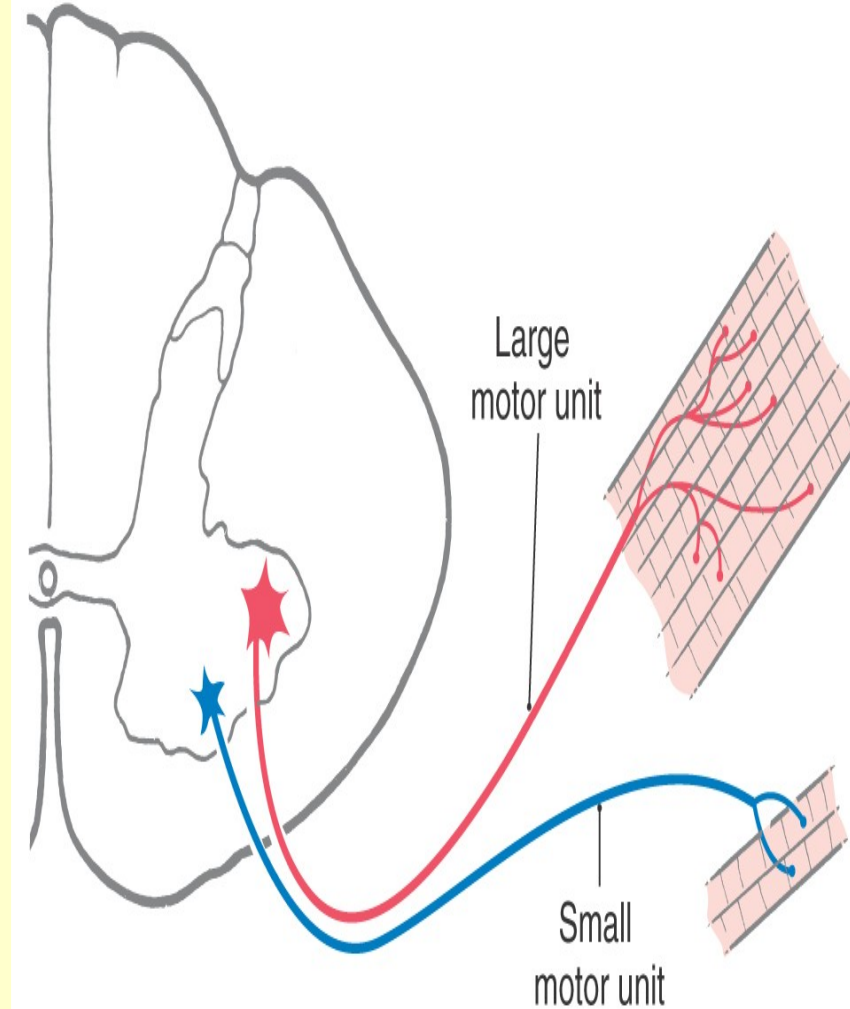
**The number of muscle fibers in a motor unit varies.**

## **Small motor unit (precise movements)**

- Small muscles concerned with fine, graded and precise movements
- i.e. muscles of the hand, extra-ocular muscles.
- there are 3 – 6 muscle fibers per motor unit = small motor unit.

## **Large motor unit (gross movements)**

- Large muscles exhibiting gross movements
- i.e. muscles of the thigh and back.
- there are 120 – 160 muscle fibers per motor



# Motor unit pool

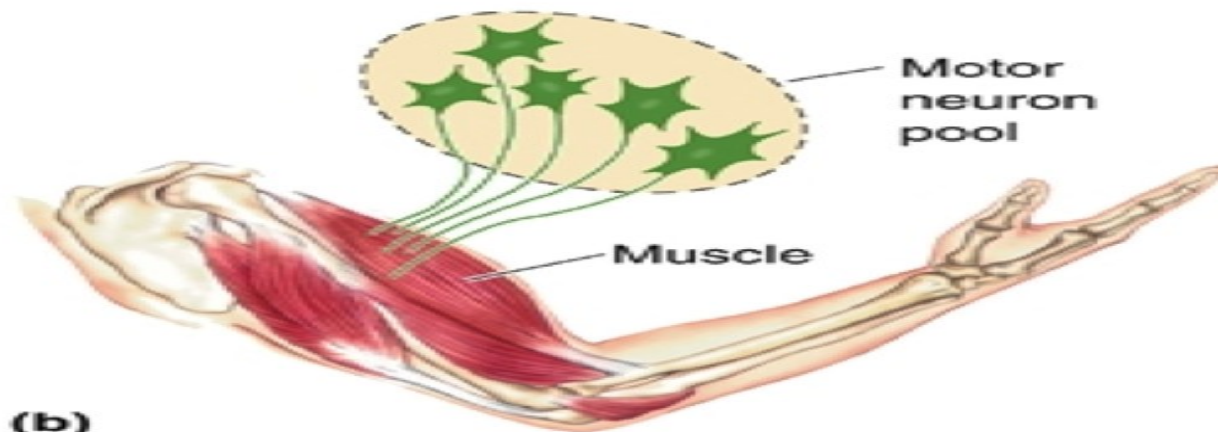


## Definition:

It is the number of motor neurons that innervate the whole skeletal muscle.



(a)



(b)

# Motor unit recruitment



## Definition:

Increasing the number of motor units activated.

When a strong contraction is needed, the nervous system may cause more than one motor unit to be stimulated.

**Stimulation of additional motor units for increased strength of contraction is called “recruitment”**

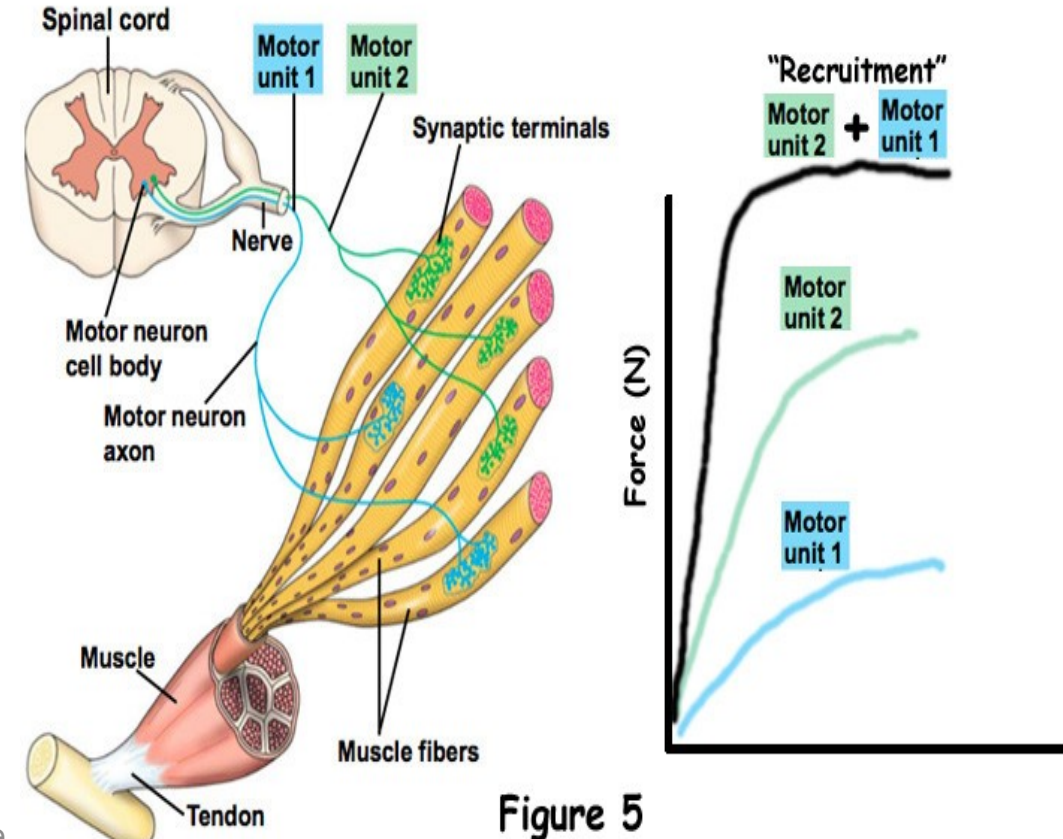
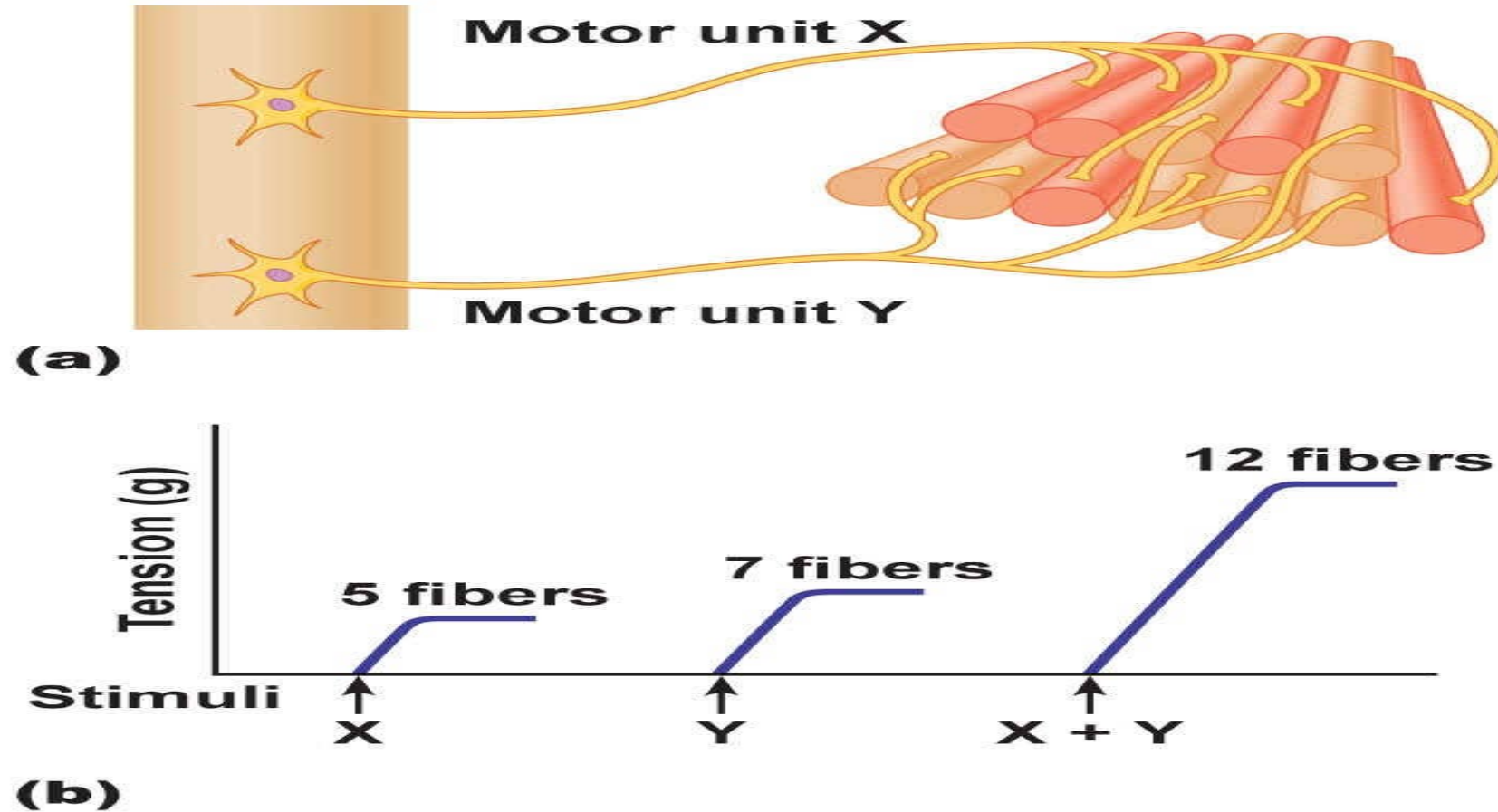


Figure 5

# Motor unit recruitment



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## Quiz



**If you want to pick up something heavier than your pencil (such as your book), you will need to have a stronger muscle contraction. In what way might you accomplish that**

- a. Stimulate more motor units.
- b. Decrease the frequency of stimulation.
- c. Decrease the refractory period.
- d. Block cholinesterase at the neuromuscular junction.

# ALL OR NONE LAW



- Sub-threshold stimulus □ No action potential.**
- Threshold stimulus □ Action potential.**
- Supra-threshold stimulus □ Action potentials with the same characteristics.**

**Action potential is an all or none event. It has fixed amplitude independent of the strength of the stimulus above the threshold value. Changes in the intensity of stimulation will increase the frequency of identical action potential (frequency-modulated).**

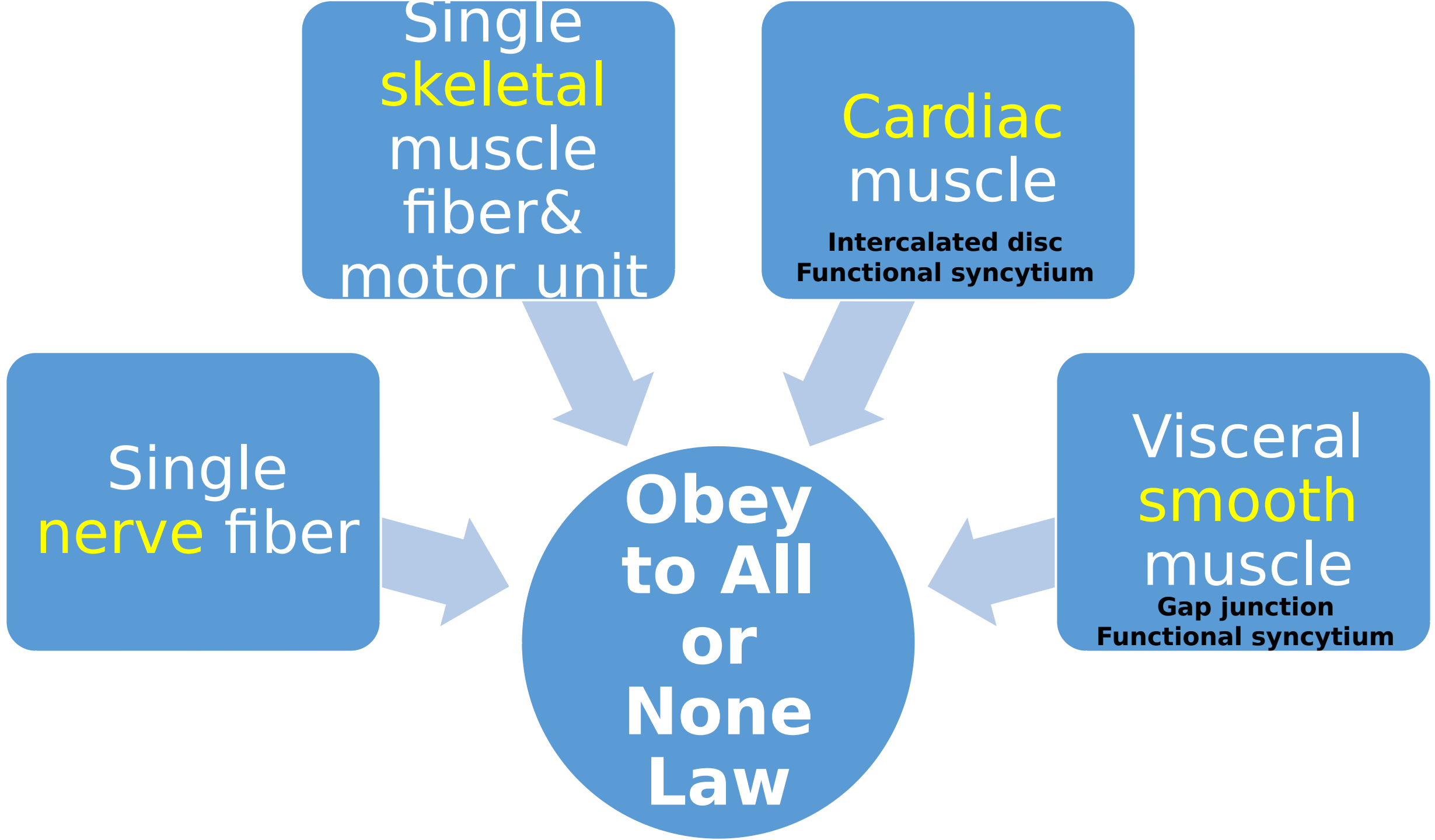
Single  
**skeletal**  
muscle  
fiber &  
motor unit

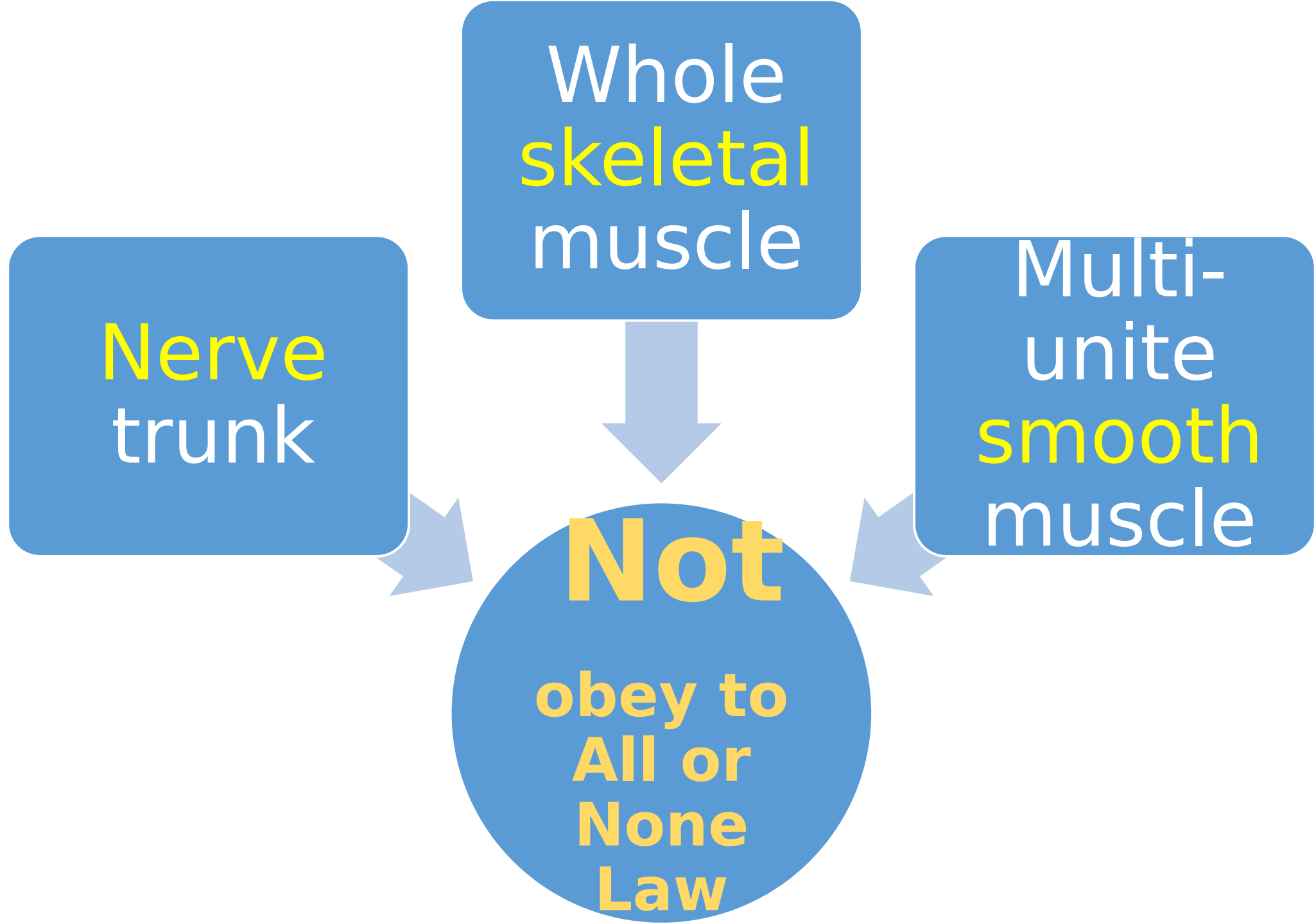
**Cardiac**  
muscle  
**Intercalated disc**  
**Functional syncytium**

Visceral  
**smooth**  
muscle  
**Gap junction**  
**Functional syncytium**

Single  
**nerve** fiber

**Obey  
to All  
or  
None  
Law**







# Quiz



## Complete:

Single nerve fiber ..... Single skeletal muscle fiber ..... Motor unit  
.....  
Atria ..... Ventricles ..... Single unite smooth muscle fibers  
.....  
.....  
Nerve trunck ..... Whole skeletal muscle ..... Multi-unite smooth muscle fibers  
..... does obey to all or  
none law. However, .....  
..... does  
not obey all or none law

# Summary



- The mechanical activity of skeletal muscle is preceded by electrical activity.
- Action potential of skeletal muscle differ from that of nerve in having more negative resting membrane potential, higher amplitude and longer duration.
- Mechanical activity of skeletal muscle in response to single maximum stimulation is called simple muscle twitch that consists of latent period, contraction and relaxation phases.
- A single nerve fiber with all the muscle fibers supplied by it is called motor unit.
- Recruitment of more motor units increases the force of contraction of skeletal muscle.
- Single muscle fiber, motor unit are obeying All-or None Law, however, the whole skeletal muscle not.

## SUGGESTED TEXTBOOKS



1. Ganong's review of medical physiology 25<sup>th</sup> edition
2. Sherwood 9<sup>th</sup> edition